[COMMITTEE PRINT]

AVIATION SAFETY RESEARCH

REPORT

PREPARED BY THE

SUBCOMMITTEE ON
TRANSPORTATION, AVIATION, AND MATERIALS

AND THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

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LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., August 1982.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
U.S. House of Representatives.

DEAR MR. CHAIRMAN: It is our pleasure to present to you our report concerning air safety research.

The report is based on a hearing last March 9 and on staff investigations. The primary focus of the report examines the role and performance of the Federal Government in assuring that research and technology to support air safety are applied.

We would like to make special thanks to Mr. Derek Monell with the Subcommittee on Investigations and Oversight for his contribution to the preparation of this report.

With best regards,

DAN GLICKMAN,
Chairman, Subcommittee on Transportation, Aviation, and Materials.

ALBERT GORE, JR.,
Chairman, Subcommittee on Investigations and Oversight.

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I. INTRODUCTION AND SUMMARY

On March 9, 1982, the Subcommittee on Investigations and Oversight and the Subcommittee on Transportation, Aviation and Materials held joint hearings on the subject of aviation safety research. Those participating included representatives of the Federal Aviation Administration, National Transportation Safety Board, National Aeronautics and Space Administration, Air Line Pilots Association, Department of Defense, Airport Operators Association, and the Aviation Consumer Action Project. The hearings emphasized the government's role in sponsoring research to more fully understand aeronautical safety hazards, and utilizing improved technologies and operating techniques.

The focus of the hearings concerned Congress' responsibility to assure continued oversight of issues involving aviation safety, and the utilization of improved technologies in areas where it could aid in avoiding accidents. Two recent air disasters gave added emphasis to the hearing and testimony centered on two main themes: one, airport and aircraft operations in bad weather; and two, cabin interiors and the crashworthiness of aircraft. The questions put forth to the witnesses were: "Could technology, that is presently available, be employed now to contribute to safer commercial air travel?"; and, "Are there areas where additional research is required?"

Deicing

One of the areas addressed in the hearing was deicing and anti-icing procedures for aircraft during bad weather operations. The central issue raised in the discussion of deicing concerned the procedures employed in deicing aircraft awaiting departure. Currently, the FAA has not set forth any specific requirement governing the deicing and anti-icing procedures. The present regulation governing aircraft awaiting departure, 14 CFR 121.629(b), states: "No person may take off an aircraft when frost, snow or ice is adhering to the wings, control surfaces, or propellers of the aircraft." This lack of federal guidance promoted numerous questions focused at deicing procedures and the optimum mix of glycol solution.

The FAA's primary means of communication with the airlines and airports concerning airport operation in bad weather is in the form of an Airport Advisory Circular. However, the Airport Advisory Circular does not deal specifically with deicing procedures and the correct mixture of ethylene-glycol and water.

The airlines who operate the deicing trucks and the manufacturers of the equipment have conducted their own research and found that heat is the primary method of properly deicing an aircraft. A manufacturer of the deicing equipment, Trump Inc., recommends in their operations manual that the glycol-water solution be maintained at 30–70 percent for mild icing conditions and 65–35 in severe conditions.

The ultimate decision of what percentage of glycol used now rests with the individual airlines that operate the deicing vehicles.

Another aspect of the deicing question concerns the purity of the ethylene-glycol produced by the two major manufacturers, Union Carbide and Dow Chemicals. Apparently the percentage of water added to the solution has varied from 7–20 percent. The net effect of this would be to cause miscalculations in getting the desired glycol-water mixture onto the airplane.

At present, the FAA has initiated a study to determine the effectiveness of ethylene-glycol deicing fluid concentrations. According to the FAA, the initial phases of the study will include a detailed review of current ground deicing inspection procedures and current guidelines. This report is due to be published in late 1982.

During the course of the hearings, it was also suggested that FAA procedures require a spotter be placed at the end of the runway during bad weather conditions to give a final check of ice and snow accumulation prior to takeoff. This is a system currently in use in the U.S. Air Force. This suggestion was praised by the majority of the witnesses. The only opposition came from ALPA, their position being that the pilot should be the sole authority of determining plane's condition on takeoff. The NTSB made a similar recommendation to FAA, Safety Recommendation A–82–9, which would require flight crews to visually inspect wing surfaces if they are delayed more than twenty minutes after their last deice check. The FAA rejected this recommendation on the grounds that the flight crews should always employ the "clear aircraft" concept without regard to specific time intervals.

SEAT STANDARDS

The question of improving seat strength standards is one area that the NTSB has been concerned with for over twenty years. Data from airplane crash sites indicate that the failure of seats injure, trap and incapacitate occupants, and create obstacles to evacuation. During testimony, several witnesses stated that many deaths and injuries in airplane accidents are probably attributable to failures of seats and cabin furnishings.

The focus of this issue is the range of G-forces the human body can withstand in a crash impact environment. The current FAA standards date back to 1956, when the propeller driven DC–3 was the workhorse of the U.S. aviation fleet. The testimony and records received from the NTSB stated that they have been recommending stronger seat standards since 1962. The NTSB recommendations of that year stated, "The Board is convinced that an increase in the minimum level of seat safety was long overdue." In responding to this and similar recommendations, the FAA has stated that they concur with the NTSB's position that there is a need to revise the current standards. In 1978, the FAA's Regulatory Standards and Analysis Branch published a report that dealt with energy-absorbing seat designs. The three significant findings of the report were.

> Analysis of previous testing indicated that the assumptions built into prior test methodology, on which current standards are based, were outdated and of poor quality.

Testing and review of accident data indicate that seat load factors (G-force tolerances) could increase significantly, which would create a 25 percent increase in the survivability of aircraft accidents.

The report also proposed new, stronger seat standards that included in-depth research and testing that were immediately applicable to revising the existing regulation.

In defense of their position, the FAA cited the continued need for research and promised that they would have definitive answers after their full-scale crash test in 1984.

Rear-facing seats for aircraft was another area of interest expressed by numerous members. DOD indicated that the military utilized rearward-facing seats because they increase occupant survivability in the event of an airplane accident.

The industry resistance to improving seat standards was based on contentions that:

Seat development costs would increase.

Seat weight would increase thereby reducing aircraft payload or increasing fuel costs.

There is no evidence that the proposed criteria would improve occupant protection over current requirements.

These claims appear dubious in light of the following evidence:

The FAA's internal research indicated that there are at least six well-equipped, independent test facilities specifically designed for contract work; either research or qualification work. Therefore, dynamic testing facilities are available to aircraft seat manufacturers in a quantity sufficient for minimizing the costs of dynamic testing.

Although the testing itself would increase the cost of seat development, individual manufacturers and the American Transportation Association conceded that this increase would be amortized and likely to produce only a small incremental unit cost increase.

More rigid seats could increase the seat weight. However, seats have been manufactured (Convair 800, Piper Aircraft) which would meet improved dynamic standards and have a seat weight comparable to other transport seats. Therefore, designing for dynamic loads is feasible and practical, and incorporation of energy-absorbing features can reduce seat weight.

FAA has failed to adequately utilize available data and technology to formulate regulatory criteria for increased seat strength standards. In each instance where research has reached a decisionmaking level, the FAA has either downgraded the project's priority or called for additional research. Fortunately, the airline manufacturers presently employ seats which exceed current FAA requirements. However, there is evidence that lives could be saved by increasing seat standards.

Post-Crash Fires

The Special Aviation Fire and Explosion Reduction [SAFER] Advisory Committee was requested by the FAA to thoroughly examine the area of post-crash fires and to report recommendations that

the SAFER Committee felt were needed to increase occupant survivability in a post-crash fire.

The basis of the SAFER Report was to examine the factors affecting the ability of aircraft occupants to withstand post-crash fires and new preventive measures being developed. In examining the data of airline accidents involving post-crash fires, the Committee noted that accident fatalities have shown a steady decrease over the last fifteen years. This is mainly due to efforts of the airline industry to comply with FAA regulations and maintain the goodwill of their customers. The airline industry now exceeds the FAA requirements for fire safety in both cabin interiors and fuel systems, and is constantly improving the materials as they become available.

The SAFER Report indicated that the primary cause of post-crash fires is the ignition of airplane fuel. Numerous fire prevention alternatives to this problem are currently being examined. These include: fuel inertion with nitrogen; fire quenching by polyurethane foam or expanding metal foil; fire suppression systems; and crash resistant fuel tanks. The most promising preventive technology is the development of antimisting fuels, as other alternatives are not yet cost effective nor compatible with airplane design.

Anti-Misting Kerosene [AMK] is the latest development in this field. AMK employs an anti-misting additive of shear sensitive, high molecular weight polymers which prevent the fuel from breaking up into a fine, highly combustible mist. The additive currently being evaluated is a British polymer known as FM–9. Estimates place the marketability of AMK as early as 1984 and definitely within the next ten years.

Another aspect of post-crash fire safety concerns the materials used in cabin interiors. Studies based on accident data indicate that the materials employed in airplanes are quite flame resistant, and that the airline industry is eager to apply new technology as it becomes structurally and economically feasible. At present, a new NASA-designed fire-resistant window may become available for commercial use following additional testing. The current FAA aircraft interior material flammability standards were revised in 1972. The SAFER Committee noted that new, improved materials and designs are currently available and exceed these requirements. The SAFER Committee also cited a lack of a universally accepted test methodology that would reliably predict large-scale fire behavior of these materials based on small-scale tests, and recommended that the FAA expedite its efforts in this area.

The recommendations put forth by the SAFER Committee were based on thirteen months of consultations with experts in the field of aviation safety. The recommendations, with the exception of Anti-Misting Kerosene [AMK], were intended to be applicable now. The FAA, however, has chosen to continue research in these areas rather than establish new regulatory guidelines.

Runway Friction Devices

In the course of the hearing, it became apparent that during airport operations in snowy and icy conditions, any method of gaining a reference about the existing runway friction was helpful information.

It was also noted that recent advances in the technology of measuring runway friction were positive to all airport operators.

The FAA, however, was distressingly unaware of some recent research that had correlated the index of the SAAB friction and the MU-Meter. Moreover, the FAA appeared to be stressing the importance of correlating friction testing measurements and aircraft performance, without having any plans to do the research necessary to make those correlations.

Given the unanimity of opinion on the value of a friction coefficient, to deter such incidents as occurred with the World Airways DC10 at Boston's Logan Airport, the Subcommittees urge that these correlations between various friction testers and aircraft performance be determined by the FAA and NASA as soon as possible. Moreover, the Subcommittees urge that the FAA prepare a projection and feasibility study for placing friction testers on the safety equipment list that qualify for Airport and Airway Development Program grants.

Severe Weather Information

Weather continues to be a significant factor in aviation accidents. During the hearing the NTSB pointed out that from 1975 to 1980 weather has been cited as a cause or factor in 52 percent of the fatal U.S. air carrier accidents and in about 40 percent of general aviation and commuter accidents.

The FAA is currently making progress in the development of systems to provide real-time dissemination of hazardous weather information to pilots and other key personnel involved in the Air Traffic Control System. These projects, outlined in the National Airspace System Plan, have the potential of providing significant safety improvements in the near future.

Aviation Safety Research

MARCH 9, 1982

WITNESSES

Jim Burnett, Acting Chairman, National Transportation Board, accompanied by Barry Sweedler Deputy for Management, Bureau of Technology, National Transportation Safety Board.

Albert P. Albrecht, Associate Administrator for Engineering and Development, Federal Aviation Administration, accompanied by Dr. Edmond J. Koenke, Director, Technical Center, Federal Aviation Administration, and Mr. Neal A. Blake.

Dr. Jack Kerrebrock, Associate Administrator for Aeronautics and Space Technology, National Aeronautics and Space Administration, accompanied by Bill Aiken, Chairman, Aeronautics Systems Division and Dick Tobias.

Raymond Siewert, Director, Engineering and Technology, Department of Defense, accompanied by Col. Paul Try, Director, Environmental and Life Sciences, and Col. Wilder, Director, Safety Policy.

Capt. J. J. O'Donnell, President, Air Line Pilots Association, accompanied by Mr. John O'Brien, Manager of Engineering and Opera-

tions, Engineering Air Safety Department, Air Line Pilots Association.

Gen. John E. Ralph, Senior Vice President, Operations and Airports, Air Transport Association of America.

Dr. H. E. Roland, Institute of Safety and Systems Management, University of Southern California.

C. O. Miller, System Safety, Inc., McLean, Va.

Edward Wronkoski, Manager, Chemung County Airport, Elmira, N.Y.

Robert Michael, Director of Aviation, Stapleton International Airport, Denver, Colo., representing the Airport Operators Council International.

Matthew H. Finucane, Director, Aviation Consumer Action Project, accompanied by Cornish F. Hitchcock, Legal Director, Aviation Consumer Action Project.

II. FINDINGS AND RECOMMENDATIONS

(1) Aviation Safety

The Subcommittees find that the U.S. air transportation system is the most advanced in the world with a remarkably good safety record. This superior safety record is due, to a large degree, to the contributions of advanced research and development. The Subcommittees recommend that the Government continue to support and fund research and development in areas of aviation safety so that safety advances will continue.

(2) Icing/Deicing

The Subcommittees find that there is considerable confusion and a lack of consensus regarding the most effective deicing procedures and the optimum formula for glycol deicing solution. The Subcommittees recommend that the FAA expedite research on (1) current ground deicing, inspection procedures, and guidelines, (2) the effect of ice and frost formation on aircraft performance, and (3) the effectiveness of various ethylene glycol-based deicing fluid solutions. The Subcommittees further recommend that the FAA, based on the research results, issue strict standards for deicing procedures and, pending that action, consider the possibility of using personal observation by airport employees known as a "spotter" to determine the condition of aircraft prior to takeoff.

(3) Seat Strength Standards

The Subcommittees concur with the conclusion of the NTSB that a key factor in the survival of most occupants in survivable aircraft accidents is the potentially lethal nature of the aircraft interior in airplane crashes and the inability of the seats and floor connections to restrain passengers in a crash. The Subcommittees find that the FAA has failed to adequately utilize available data and technology to formulate regulatory criteria for increased seat and floor strength standards. The Subcommittees recommend that the FAA immediately upgrade seat and floor strength standards in line with the preponderance of data and evidence, while continuing plans to test seat strengths, including rearward-facing seats, in the proposed full scale crash test.

(4) Runway Friction/Traction

The Subcommittees concur with the NTSB that a more precise and reliable method is needed to determine the friction coefficient of runways under various conditions for various aircraft. The Subcommittees recommend that the FAA, with support from NASA, expedite research underway to validate current runway friction measurement

devices, and to assure that the friction measurement correlates to the performance of various aircraft. Should the correlation be validated, the Subcommittees recommend that runway friction measurement devices be made available to airport operators through the Airport and Airway Trust Fund. The Subcommittees further recommend that the FAA re-evaluate their position on the feasibility of preventing adverse runway conditions by investigating the potential of heated runway surfaces to preclude snow and ice buildup.

(5) Post-Crash Fire

The Subcommittees find that significant increases in crash survivability could be realized through the control and prevention of post-crash fires. The Subcommittees find that the FAA, NASA, and industry have made significant progress in this area, particularly with regard to anti-misting fuel and fire blocking layer research. The Subcommittees recommend that the FAA adopt new regulatory guidelines based on this new technology as encouraged by the SAFER Committee.

(6) General Aviation Flight Data Recorders

The Subcommittees find that the NTSB, FAA, and NASA investigations and research would be enhanced by more detailed information regarding aircraft performance and human responses in aircraft accident situations. The Subcommittees recommend that the FAA, with assistance from NASA and the Department of Defense, support additional research and development of small, lightweight, inexpensive voice and digital flight data recorders so that their installation and use will be widely accepted by the general aviation community.

(7) Distance-To-Go Markers

The Subcommittees find that the installation of distance-to-go markers have provided Air Force pilots with valuable information to enhance situational awareness during takeoff and landing phases of flight, particularly during severe weather conditions. The Subcommittees recommend that distance-to-go runway markers be made available to airport operators through the Airport and Airway Trust Fund.

(8) NTSB Funding and Personnel

The Subcommittees find that, due to the occurrence of several major transportation accidents this fiscal year, the NTSB budget is under severe strain. The Subcommittees recommend approval of a NTSB supplemental appropriations for fiscal year 1982.

The Subcommittees find that the NTSB accident investigators are no longer required to have formal training in accident investigations, and that this may have a severe impact on the quality of NTSB investigations as formally trained investigators move on or retire. The Subcommittees recommend that the NTSB reinstate their previous requirement for a formal accident investigation education for appropriate employees.

(9) FAA Funding

The Subcommittees find that FAA research, particularly aviation safety research, has been severely limited by an inadequate budget for fiscal year 1982. The Subcommittees recommend that the FAA include in their supplemental appropriations request adequate funding to bring the budget up to the fiscal year 1981 level for aviation safety research activity.

(10) Severe Weather Information

The Subcommittees find that many aviation accidents are due, in large part, to severe and hazardous weather conditions. The Subcommittees recommend that the FAA expedite the research projects outlined in the National Airspace System Plan which would provide real-time dissemination of hazardous weather information to pilots, air traffic controllers, and key personnel of the Air Traffic Control System. The Subcommittees further recommend, in the interim, that better coordination be established between the National Weather Service and air traffic controllers so that reliable weather information is made available to pilots, particularly at or near airports, to assure that aircraft are not vectored into hazardous weather.

III. SUMMARY OF TESTIMONY BY ISSUE

(A) U.S. Aviation Safety

Congressman Glickman, Chairman of the Transportation, Aviation and Materials Subcommittee, commented on U.S. aviation safety:

I don't think there is any question that our Nation's air system is the best and the safest in the world, but the recent accidents in Boston and Washington, as well as in numerous other accidents involving other types aircraft, remind us that the impact of severe weather can be unpredictable and disastrous. We need to be sure that our government continues to make progress in assuring that our aviation safety needs are being pursued vigorously.

Congressman Albert Gore, Jr., Chairman of the Investigations and Oversight Subcommittee, also commented on U.S. aviation safety and on the purposes of the hearing:

Despite the impressive overall positive trends in aviation in the past decade, this country is still plagued by periodic avoidable disasters in our airline system.

These accidents serve as unfortunate, but forceful catalysts for the Congress to review the Federal Government's role in air safety. Sadly, there is always an element of "too little, too late" to after-the-fact proceedings like this. By the same token, it is difficult to imagine a more propitious time to be reviewing our progress in the field of air safety.

Moreover, in that this is a committee charged with overseeing the Federal Government's scientific and technological undertakings, we are particularly interested in how research, development, and technology can contribute to preventing occurrences like last January 13.

Congressman Walker, Ranking Minority Member of the Investigations and Oversight Subcommittee, added:

Our jurisdiction in this committee covers research and development. We will try to determine today what research is needed to make air travel even safer than it now is. The statistics show that commercial air travel on scheduled carriers is the safest form of travel. As we all know, statistics can be misleading. No other form of travel is so tightly controlled; no other form of travel is so highly regulated; no other form of travel is so closely scrutinized by the Federal Government; and no other form of travel has been the beneficiary of so much federal research. All of this should give us a great sense of security.

Congressman Dunn, serving as Ranking Minority Member of the Transportation, Aviation and Materials Subcommittee, cautioned Members of the Committee:

I would only make one statement, and that is that I am a pilot and I use the same runway that Palm 90 used every single weekend going in and out of National, and yet I do not feel qualified to comment on that accident or the accident at Logan, and would urge the members of the committee to keep this hearing within the realm of the things that we do have control over, and that's the general issues of safety as it pertains to runway conditions, seat control, and not get into what caused the last two or three accidents.

General John Ralph, Senior Vice President of the Air Transport Association of America:

Let me first start by pointing out that this Nation's air transportation system is the safest and the most advanced form of public transportation in the world, and we shall take every action necessary to keep it that way.

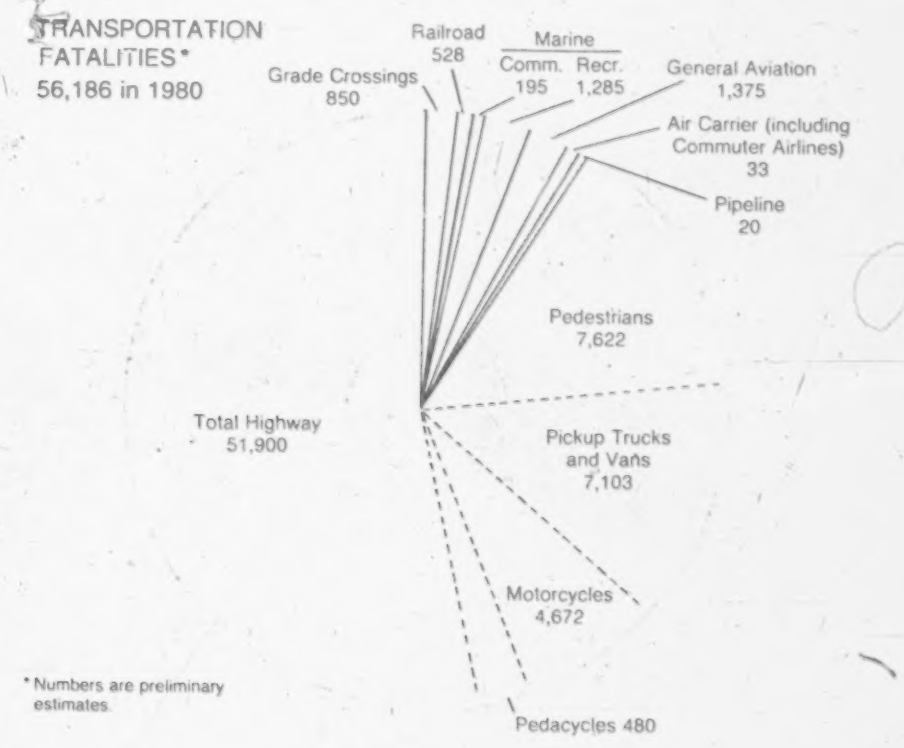
I believe it is important to recognize that research and development has contributed significantly to the improvement in flying safety over the years. Research in aerodynamics and aeroelasticity has given us airplanes of greater efficiency and greater safety in their flight characteristics. Turbo jet engines and solid state electronics are specific examples where more reliable systems have contributed to the outstanding safety record of the airlines.

In our view, it is very important for the Government to continue to fund research and development so that continuing improvements in efficiency and safety can be realized.

National Transportation Safety Board statistics supported the comments made at the hearing:

U.S. SCHEDULED DOMESTIC AND INTERNATIONAL PASSENGER SERVICE

	Fatal accidents per million aircraft miles	Passenger fatalities per million aircraft miles	Fatal accidents per 100,000 aircraft departures
1951–55	0.012	0.201	0.253
1956–60	.008	.195	.197
1961–65	.006	.148	.160
1966–70	.003	.073	.134
1971–75	.001	.094	.114
1976–80	.001	.056	.091



(B) Icing/Deicing

Mr. James Burnett, Acting Chairman of the National Transportation Safety Board:

Let me first turn to aviation safety research and weather considerations. Weather is a significant factor in aviation accidents involving all types of opera-

tions—air carrier, commuter and general aviation. From 1975 to 1980 weather has been cited as a cause or factor in about 40 percent of the fatal U.S. general aviation and commuter accidents, and in 52 percent of the fatal U.S. air carrier accidents. Four thousand people lost their lives as a result of these accidents.

The Safety Board has been concerned with aviation weather problems for many years and has made numerous safety recommendations regarding weather facilities, services and procedures to the Federal Aviation Administration and the National Weather Service.

The Safety Board has also been very concerned with the area of aircraft icing, including both airframe icing and engine icing. The board recently issued 10 related recommendations based on its continuing investigation of the crash of Air Florida Flight 90 on January 13, 1982, near Washington National Airport. These recommendations addressed the problems of engine inlet pressure probe icing, faulty engine instrument readings caused by engine inlet pressure probe blockage, the use and effectiveness of deicing fluids, and extended delays during ground operations in inclement weather prior to departure. The board recommended that the FAA advise operators of the hazards of an accumulation of snow on aircraft while on the ground after deicing, study the effectiveness of deicing techniques, and publish guidelines establishing adequate and safe deicing and anti-icing procedures.

Last year the Safety Board conducted a study and published a special report on the problems of aircraft structural icing. The study showed that the present system of forecasting icing conditions is inadequate in that it forecasts icing in general terms of intensity and does not consider the wide variation of ice accumulation characteristics of different aircraft and different deicing/anti-icing systems in use. The Safety Board subsequently made recommendations calling for the combined efforts of several agencies to develop economical instruments to measure the principal icing parameters of temperature, liquid water content and drop size in the atmosphere, develop methods to forecast these parameters, and publish the effects of variations of these parameters on individual aircraft types.

The result of this work, if accomplished, would provide icing forecasts that would be directly applicable to specific aircraft and allow the certification of an aircraft to operate in those icing conditions demonstrated to be safe for that particular aircraft.

Dr. Koenke, Director of the FAA's Technical Center, briefed the committee on their icing and deicing research:

Our icing program addresses possible enhancements which could improve flight safety. We rely upon and work closely with NASA and the DOD through interagency agreements to obtain relevant information in a cost effective manner.

Under interagency agreement between the FAA and the U.S. Army, we, along with NASA and other elements of DOD are making improvements in icing simulation technology. Improvements in the HISS (Helicopter Icing Spray System) simulation will be completed in fiscal 1984.

The atmospheric criteria being used today is the same for helicopters, transport category, and general aviation aircraft and is considered altitude independent. Therefore, an element of our program is to reexamine atmospheric icing data to confirm their applicability to each category of aircraft. We are working in close harmony with NASA, the U.S. Army and the U.S. Air Force. This effort will initially provide atmospheric data for flight into supercooled clouds and will be completed during the latter part of fiscal 1982. Similar data related to snow conditions will be completed by late '84.

This photograph depicts the unique ground-based icing simulation facility commonly referred to as the "Ottawa Spray Rig." This facility is owned and operated by the Canadian National Research Council. Extensive cooperative efforts exist between the United States and Canadian Government through a memorandum of understanding. The helicopter under test is the Bell Model 412.

The Ottawa Spray Rig has been used over the past 20 years and virtually every helicopter, U.S. and foreign, has at one time been tested in this facility.

I have thus far only addressed helicopters. This photograph is the Piper Saratoga, the second single-engine, fixed-wing aircraft to seek certification for flight in known icing conditions. While our program was initially directed

at helicopter icing, it was expanded to include transport and general aviation category aircraft during fiscal 1981.

This next photograph depicts the ground icing process. The system shown is the Trump Model D40–D. Significant progress has been made in recent years, by industry, in solving the economic and ecological problems associated with ground deicing.

In 1981, the FAA initiated an effort to study the effectiveness of ethylene glycol-based deicing fluid concentrations. The initial phases of our study include: 1) a detailed view of current ground deicing, inspection procedures, and current guidelines; and 2) a review of recent studies of the effect of ice and frost formation on aircraft performance. This program forms the basis for information which may identify additional research and development required to assure flight safety. Our final report will be published later this year.

Congressman Glickman questioned the FAA on deicing standards:

Mr. GLICKMAN. I would like to ask specific questions on the areas of research. The first one is icing. I was amazed to find out during the Air Florida crash that there were no standards for the mix of glycol and water that have been issued by the FAA. So, therefore, the airlines have complete and total discretion as to what percentage of mix to use. How come there have been no standards in the whole issue of deicing an airplane on the ground in terms of what kind of materials to use, the optimum mix of glycol and water, and the related issues?

Mr. ALBRECHT. We have some difficulty with that question, Mr. Chairman, because basically our task is research and development, and the issuances of standards is a regulatory procedure. It is carried out under Mr. Lufsey, the associate for aviation safety, so I can't answer directly why there have been no standards. We can describe the R&D that we do to support Mr. Lufsey, who is our principal customer.

Mr. GLICKMAN. Well, what are you doing in terms of R&D on deicing solution?

Dr. KOENKE. Back in February we basically initiated a program—this was February, 1981—we initiated a program to begin, and as I said in my testimony, to look at ethylene glycol, the mixture, and the optimum mixture to be used as a function of precipitation level, type of precipitation, how long it would be effective as an anti-icing versus a deicing technique, what the mixture should be for deicing and then what the mixture should be for anti-icing. That's included in a program plan that we have developed over the past year and is now in coordination with AVS.

Mr. GLICKMAN. When did you start this program?

Dr. KOENKE. February 1981.

Mr. GLICKMAN. OK.

As I understand it, the glycol solution is what we have been using in this country from time immemorial to deice an airplane.

Dr. KOENKE. Yes, sir.

Mr. GLICKMAN. And I understand it, its primary function is as a deicer, not as an icing preventative. Is that a fair statement?

Dr. KOENKE. It can be used as an anti-icing agent, I believe, if it is used at 100-percent quantity.

Neal, maybe you want to comment on that.

Mr. BLAKE. It is primarily for removing the ice from the aircraft, yes. It does provide some protection if applied at or near full strength for a period of time. Obviously, as precipitation continues to fall it does dilute the effectiveness. A part of our program is to look at concentration versus various levels of precipitation to define what the appropriate use of that material would be.

Mr. GLICKMAN. But to the best of your knowledge there are no substitutes to glycol as a deicing agent? We have been using this for 30 years as the base deicing solution?

Mr. BLAKE. That's correct.

Mr. GLICKMAN. Is any of your work being done to try to find substitutes to glycol?

Dr. KOENKE. I don't believe that that's included in the program at this point, but I could defer to Dick Adams, who is our technical expert in this area.

Dick, do we have any alternatives to ethylene glycol?

Mr. ADAMS. None known today.

Mr. GLICKMAN. And again, there are no regulatory standards, to the best of your knowledge—realizing you are not in the regulation area—that would instruct the airlines on what mixtures to use or even when to use them?

Mr. ALBRECHT. I suspect that is right, Mr. Chairman. Now, whether there are company standards that we monitor or not I don't know.

Mr. GLICKMAN. I personally just find that unbelievable in light of all the other areas of Federal regulatory efforts in aviation. This one just seems to have fallen through the cracks, but I suppose now that an accident occurred you will continue to enhance your research in this area.

Congressman Hollenbeck asked Captain O'Donnell, president of the Air Line Pilots Association, about deicing procedures:

Mr. HOLLENBECK. On the subject of deicing procedures, I have a two-part question. Do you have any suggestions for improvements in the procedures, and are you aware of any additional material or studies that we may not have been aware of today for improving those procedures or matters along those lines.

Captain O'DONNELL. Mr. Hollenbeck, I think it is important that the response that we give has to attach itself to what we have read in the newspapers. I think there is clear reporting in the newspapers in Washington to suggest that within the industry some segments of the industry do not have a clear understanding of what the deicing procedures are or what the mixtures should be. It is obvious, again from the newspaper reports, that there is a feeling that there may be a contributory cause here.

Yes, there have been studies, and some by the U.S. Air Force as far back as 1957, that stated research done by the military as to how the glycol mixture should be put together, what ratios, what additives should be put on to it, what precautions should be made in the glycol and the anti-icing and deicing procedures. In 1976, that study was updated, and we have copies of that. If the committee requests it, we will provide it for the record. Those are available; they are in the public record; they are U.S. Air Force research programs.

Mr. HOLLENBECK. Would it be practical to have a deicing mechanism or truck holding the deicing spray present near the beginning of the runway in this kind of weather situation to be available for last-minute check and procedure?

Captain O'DONNELL. That is a possibility. You know, I have flown for many, many, many years out of Boston. We get a little bit rougher weather up there than you do down here in Washington, D.C. Every winter we do go through a series of storms up there that do require de-icing the aircraft and anti-icing before takeoff. Very simply, the airlines that I am familiar with had specific procedures to brush the snow off the aircraft, water it off, and put a coating of glycol on. The mixture was awfully important.

In those days—and I have not flown for the last 10 years as an airline pilot—but in those days we made sure that the second officer and our flight engineer went back and checked the surface of the wing. If we had a question, we would make him open the door, go out, and walk around the aircraft, because once you push those throttles forward, he is on board with you. You know, when you rotate it, you hope it flies. Therefore, the only way to make sure of that is to make the decisions yourself.

I cannot accept one of the statements I heard this morning by someone with respect to how glycoling is done. I think that the glycol systems of today are no improvement over what they were 20 years ago. There is very little improvement on it; I am not sure you need any improvement on it. But there has to be closer control over the quality and the mixtures and the timing and the application of it. We used to go to a hangar and have them deiced, have the snow brushed off and hosed down, and 15 or 20 minutes before we are cleared for departure, we would get a glycol.

I think there are procedures available. I am not sure necessarily the airlines would buy it because of the economics of having a truck at the end of the runway. It is clear, from almost every study that I have heard, and particularly the Air Force studies, you do not put glycol on an aircraft that has snow on it; it will melt and turn to ice.

Dr. C. O. Miller, President of System Safety, Inc., commented on the icing issue:

In the matter of icing, the current investigation of the Air Florida Flight 90 accident has highlighted at least a couple of voids in our knowledge, as I think you may have realized. First there is a question of how a flight crew can be expected to know when an ice and snow condition has reached a critical level during protracted ground operations prior to start of takeoff roll, or in flight for that matter.

The suggestions heard at the (NTSB) public hearing this past week were either rather crude, like "How you find this out is run your hand across the top of the wing," or bureaucratic when the FAA keeps coming back and saying, "The pilot shall not begin the takeoff roll with snow or ice on the aircraft."

I do not think there is any secret, and I think the facts are irrefutable that icing at least was involved in the diminished power of takeoff. I think that the degree to which wing ice was involved was not fully discussed, although there was some testimony there.

I know of no one who does not agree that confusion reigns concerning the deicing procedures. Like you and others at this hearing so far today, it is again nothing short of incredible.

Congressman Gore asked Dr. Miller about glycol deicing:

Mr. GORE. What is the optimum mix, Dr. Miller, of glycol and water?

Dr. MILLER. I do not think it is known. If you go on the basis of the people who testified at the hearing, who seemed to have the most operational experience—and I think that is all you have to go on right now—I think you are talking about first getting rid of the ice to begin with, deicing it with steam or hot water; and then depending on the particular environmental conditions, again a judgment call, you can go as high as 65 percent glycol. But I do not believe there is anything definitive, in a research sense, that is going to answer that question. It was posed by several of the people at the board, and nobody in that room seemed to have any answer to it.

Mr. Matthew Finucane, Director of the Aviation Consumer Action Project, indicated other concerns were expressed at the NTSB hearing:

In the hearings on the accident of Air Florida yesterday there was a discussion of the NTSB's recommendations that the FAA do research into deicing. They put on a witness from the FAA yesterday to explain what it meant that the FAA was now expediting its research into deicing. What it meant was that they had a staff of two people. They had been working since February of last year, and they had now contacted two carriers as to what their deicing procedures were, and they had no actual planned research for actual application of deicing fluids to aircraft wings.

When they say they are "doing research," I really think the committee needs to take a close look, like you are doing today.

Congressman Dunn asked about the possibility of having an observer check for aircraft icing before takeoff:

Congressman DUNN. It occurs to me that there might be another simple solution for aircraft as to whether or not they are in a deiced condition at the moment that they roll onto the active runway, and that would be rather than spend a million dollars of research during periods of snow or sleet, and sleet and rain, that we station one observer at the point that they roll off the taxiway and onto the runway given the fact that the pilots in the big aircraft virtually can't see their wings, let alone the body which none of us can see, and simply a thumbs up or a thumbs down as to whether that aircraft does or does not have ice on it. Now, that is no research dollars; that's one man out of a number of people that work at National for maybe a period of five hours a month at the most. Now why isn't that an effective, immediate, clearcut solution to the problem?

Mr. BLAKE. I think there are many things that one can do to address that problem.

Mr. DUNN. Let me rephrase that: What's wrong with my idea of an observer in a little tower there during periods of adverse weather that gives a thumbs up or thumbs down as to whether or not there is ice on your wings?

Mr. ALBRECHT. I'm not sure there is anything wrong with it, Mr. Dunn. It is not an R&D problem, as you point out, but we will pass it along.

Dr. C. O. Miller added:

I am sorry Mr. Dunn is not here. He had an interesting suggestion—stationing an observer at the active runway—and I wanted to tell him why I do not think it would work: it does not cost enough.

(C) Seat Standards

Mr. Jim Burnett, Acting Chairman of the National Transportation Safety Board:

The Safety Board and its predecessor, the Bureau of Aviation Safety of the Civil Aeronautics Board, have urged the FAA to come to grips with the issue of aircraft crashworthiness in general, and the adequacy of the crashload factors in the Federal aviation regulations in particular. Time and again, the Safety Board's investigations have shown that occupants of aircraft, both in general and in air carrier accidents, could have survived if their seats had remained attached to the cabin floor.

Only recently, the Safety Board completed a special study on cabin safety in large transport aircraft which contains an overview of the board's efforts in this area since the early 1960 s, and which showed ample evidence, from accident investigations as well as from research, that human tolerance levels are significantly greater than the FAA officially maintains. The evidence includes a substantial body of work done within the FAA itself. It is the Safety Board's experience that the limiting factor in the survival of most occupants in survivable accidents is not their tolerance to crash forces, but the lethal nature of the aircraft interior and the inability of the seats to restrain the passengers.

The FAA stands virtually alone in the safety research community with respect to its insistence that the human body, when restrained by only a seat belt cannot withstand significantly more inertial forces than those to which present passenger seats are designed.

Congressman Walker questioned Mr. Burnett on the issue of seat strengths:

Mr. Walker. Am I correct that the seats that are in most commercial airplanes flying today are less rigid in terms of their structure than the seats that are in automobiles?

Mr. Burnett. That's correct.

Mr. Walker. You point out in your testimony that the FAA has taken up a study of crashworthiness and is investigating the seating standards. You also indicate, however, that a data base which has been previously developed in order to get at principally the things the FAA claims to be looking at is not being used. Are you charging that we have the FAA out reinventing the wheel in order to, I take it, delay the implementation of the standards that you have suggested?

Mr. Burnett. I believe my predecessor, Chairman King, perhaps used that in testimony and I would not retreat from that position. We think that they have a great deal of research. Much of it is their own through the excellent work of the Civil Aeromedical Institute in Oklahoma City. And we think that they are just not using what they already have. Certainly we haven't achieved the final solution yet, but do we have to wait for eternity in order to begin the process of improving?

Dr. Edmond Koenke, Director of the Federal Aviation Administration's Technical Center, summarized the FAA's seat/restraint system program:

Concurrently a joint effort with the U.S. Army to determine limits of human tolerance to injury is being accomplished. This effort is scheduled for completion in early Fiscal '83 and will provide the data needed to complete the efforts on the seat/restraint system and occupant interface. The data currently in our possession is mostly applicable to young, healthy individuals, totally restrained and not representative of the commercial aviation public. The tests currently being conducted will define a range of human tolerance limits applicable to varied physiological makeups and be more representative of the flying public.

A critical parameter is knowledge of human tolerance to vertical acceleration forces which is extremely limited and virtually little or no information has been developed in many years. The vertical forces experienced during a crash impact is a critical factor in trauma fatalities because of the relative stiffness of the human spinal column. This program will provide the much needed data and also provide input for validating our mathematical model.

In 1984, the FAA plans to conduct a full-scale crash test of a Boeing 720 aircraft. The purpose of this test will be to evaluate the performance of antimisting fuel additives as well as to validate the crashworthiness techniques which I have just discussed.

This full-scale test will involve a fully instrumented, remotely piloted aircraft crashed in a pre-selected mode determined from results of the crash environment program. Specifically, the crash test experiments will focus on the performance of current, modified, and new occupant seat/restraint systems.

Congressman Glickman asked about rearward facing seats:

Mr. GLICKMAN. If I may just interrupt you, has anybody ever thought about turning the seats around like they do in the military so that you don't go forward, that you just go back into the seat?

Dr. KOENKE. Yes, sir, that's been thought of.

Mr. GLICKMAN. I know it has been thought of, I see it in almost every military airplane that I have ever been on. Has that ever been thought of in terms of requiring that as a part of commercial aircraft seating?

Dr. KOENKE. What that would require is a redesign of the seat which would add significant weight to the seat, and there would be a weight penalty that would have to be paid to turn those seats around.

Mr. GLICKMAN. OK. We can talk about that later.

Dr. KOENKE. OK.

Mr. GLICKMAN. It is curious that all the research is going this way. Just think, if you turned the seat around the body wouldn't go that way at all.

Dr. KOENKE. I believe that is going to be included in the 720 crash test, but I will defer to one of my experts on that.

These issues were raised again during questions on the safety research being conducted by the FAA:

Mr. GLICKMAN. I would like to pursue for a moment the area that was raised by Mr. Burnett on the issue of seats and crash survival and the human tolerance, and you had your viewgraphs about that. I will repeat what Mr. Burnett said: "The FAA stands virtually alone in the safety research community with respect to its insistence that the human body, when restrained by only a seat belt, cannot withstand significantly more inertial forces than those to which present passenger seats are designed."

I wonder if you would care to comment on that? I mean, by implication he is saying that you are fighting all the other scientific evidence in this area—and maybe you're not—and I think you deserve a chance to respond.

Dr. KOENKE. I don't believe that we are fighting scientific evidence. I believe that we are looking for scientific evidence, and we have a program with the U.S. Army to try to determine the human tolerance levels. A lot of work has been done, and it is a very controversial issue, Mr. Chairman. A lot of the work that's been done has been done on young healthy males and is really not representative of the flying public. The seat design as the specs call for, 9–G's longitudinal, 4.5–G's downward, 2–G's upward, and 1.5–G's sideways.

The question that has to be looked at is whether or not the human being can survive G levels at higher values than those designs. Now, I think it could be shown very easily that even for a very young healthy pilot, for example, if he is a 4–G environment for very long, not only will he black out but will eventually die. It is a question of the length of time over which these G's must be sustained. Now we are doing work with the U.S. Army; we are also on cadaver-type work; we are also doing work in preparation for monitoring the actual impulses that would be measured in the 720 crash test. So there is work going on; and, yes, it is a very controversial issue.

Mr. ALBRECHT. It is also a system problem, Mr. Chairman. You have to look at the human occupant, you have to look at the seat attachments to the floor as a total system. People say, "Gee, why don't you make the seats a lot stiffer?"

Well, one product of that would be to pass heavier loads onto the human being sitting in the seat. So you certainly need to take care of things like seat attachments where it shouldn't come lose, but it is the system program we are looking at.

Mr. GLICKMAN. One of the points I think is the implication of Mr. Burnett's testimony that this idea may be researched to death when in the meantime we could design some improvements in crashworthiness of seats, and I think we have made our point. I assume that the crash of your Boeing 720 will take into account some of these things.

And you also indicated you were also going to install some seats in reverse position?

Mr. ALBRECHT. Let me check on that one second.

Yes, there will be reverse seats.

Mr. GLICKMAN. Do you have any idea on the impact, what the impact of putting a seat in a reverse position would be in terms of the G force and the——

Dr. KOENKE. I think it depends on the seat because, depending upon the structure of the seat, the back could collapse. You know, it depends upon how that seat is built.

Mr. GLICKMAN. Do you know why the military has traditionally, in many cases, gone to a seat that faces to the rear, actually faces to the rear?

Dr. KOENKE. Probably because they feel that it is a safe way to go.

Mr. GLICKMAN. It is curious, and I think it is something that shouldn't be neglected in your studies.

Congressman Gore continued the questioning:

Mr. GORE. Do you think that the current design of passenger seats is right around the range that is at the upper limit of what human beings can withstand?

Dr. KOENKE. I would like to wait until the data is in, sir. I do not have an opinion as to whether it is right or wrong.

Mr. GORE. Well, I know that you covered some of this in your initial presentation, but in June of 1980 GAO said that you were waiting too long, and here it is almost spring of '82. And I take it that you have said in your presentation that you hope to come up with some answers soon, perhaps by this summer, is that correct?

Dr. KOENKE. We will have some answers this summer, but we will not have definitive answers until after the Boeing 720 crash test in fiscal 1984.

Mr. GORE. Well, you don't escape one of the central points of this hearing, we are trying to urge you to move faster, and I think that the overwhelming majority of the American people have precisely the same desire. And I would hope that you are a little bit uncomfortable with the pace thus far, and that in the wake of these hearings and the incidents which cause these hearings that you would move faster.

Mr. ALBRECHT. You could say we are uncomfortable, Mr. Gore.

Mr. GORE. All right.

Congressman Gore questioned Mr. Raymond Siewert, Director of Engineering and Technology for the Department of Defense:

Mr. GORE. Is it the view of the Department of Defense that the current standards for airplane seats allow the seats to withstand a force of G's significantly less than the force which the human body could withstand?

Mr. SIEWERT. I am afraid I am not the one to answer that, and I do not believe we have an expert on that particular subject, unless Dr. Carper from the Army might be able to.

Dr. CARPER. May I revert back to an earlier question relative to this?

Mr. GORE. Sure.

Dr. CARPER. There is an active interagency agreement in the specific area of structural crashworthiness with the Federal Aviation Administration and the Army. There are active programs. For about the last two years, the Civil Air Medical Institute at Oklahoma City, as part of establishing human tolerance limitations, has conducted between 30 and 40 dynamic sled tests specifically for the Army. So there is a fair amount of exchange between the Army and the FAA in this area.

On the other issue, the Army has a military standard relative to the design of a crew seat: Mil S. 58095. That does call for designing to and testing to

G-levels which are considerably higher than what we talked about earlier relative to commercial seats.

Mr. GORE. So the Army's view would be that the current seat standards, at least as they compare with the standards you just cited, are deficient?

Dr. CARPER. I have to get back to the total system aspect of designing for crashworthiness. The seat standard itself is only one part of that aspect. We feel that seats, yes, could take more of the load and protect the occupant in the seat at higher loads than 9 G's.

Mr. GORE. That is a critical point, and I appreciate that. Earlier the FAA had been criticized by the NTSB as being isolated in its position that this is an uncertain question, and they turned to the Army to buttress their position. Evidently the Army does not really buttress their position, at least insofar as it is isolated to the question of the seats.

To put a point on that, we do not need a lot more research—evidently, most people agree—to determine whether or not the seats can be improved. They can be improved, and it will do a lot of good, because the human body can withstand more than what the current seats will allow the human body to withstand. So we need to move much faster there and not try to answer a question that has already been answered.

Congressman Glickman asked Mr. Siewert about rearward facing seats:

Mr. GLICKMAN. We talked a lot about crashworthiness and seats. Mr. Dunn, Mr. Walker and I have all asked questions about the rationale why, in so many military aircraft, seats are faced toward the rear as opposed toward the front. I wonder if you might comment on that?

Mr. SIEWERT. Mr. Chairman, I believe the rationale had to do with increased survivability in the event of crash. Unfortunately, we do not have any data available with us. We can attempt to search the safety system to see if there is any data that indicates that rearward-facing seats are safer or more survivable than forward-facing seats.

Mr. GLICKMAN. It sounds to me as if a common sense decision was made about 30 or 35 years ago how to turn seats around.

Mr. SIEWERT. I believe you are right, sir. The Navy still uses rearward facing seats on all passenger carrying aircraft that operate from the aircraft carriers.

Mr. GLICKMAN. I would like you to search your records, if you would not mind, on that issue.

Mr. SIEWERT. We certainly will, sir.

[The information follows:]

AVIATION SAFETY RESEARCH

Mr. GLICKMAN. Why in so many military aircraft, are the seats faced toward the rear as opposed to the front?

ANSWER. The Navy and Air Force have been installing rearward-facing aircraft passenger seats in their transport aircraft since the early 1950s. The decision to use rearward-facing seats was based upon acceleration research which showed quite convincingly that a person can tolerate much higher crash forces when facing to the rear. Also, during the 1940s and 1950s, the US Army Air Force, Royal Air Force, US Navy and the US Air Force studied propeller-driven aircraft mishap data and concluded that survivability was enhanced with the use of rearward-facing seats. Since the advent of the all-jet Air Force transport force, no new conclusions, based upon mishap data, have been drawn by Air Force on the rearward vs forward-facing seat issue. The lack of aircraft with both types of seats, as well as the relatively small number of survivable aircraft crash mishaps which could be studied, has made this a difficult subject to analyze statistically. Even so, the preponderance of evidence and data favors the use of rearward-facing seats.

A very thorough review of this subject, one which parallels the US Air Force experience with passenger seats, has been prepared for the Aerospace Medical Panel of AGARD/NATO and is published in AGARDograph No. 221.

In addition, a comprehensive report entitled, "U.S. Navy Approach to Crashworthy Seating Systems," has recently been completed by Mr. Marv Schulman at

the Naval Air Development Center, Warminster, Pa. This report covers twenty-five years of development in crashworthy seating and is available if desired.

Dr. C. O. Miller, President of Safety System, Inc., commented on the issue of FAA seat standards:

I walked in here this morning during the presentation by the FAA. I can only say that Dr. Hugh DeHaven must have turned over in his grave. If you are not aware of Dr. DeHaven, he was the gentleman in the Thirties and the Forties who identified the principles of crash injury prevention. I personally in 1962 did a survey of the available literature which dealt with t' e knowledge in terms of human tolerance and things of that type.

For me to hear a major U.S. official today say that we have to learn more about human tolerance to restrain acceleration in polite terms is incredible. I could think of some other terms, but I do not believe your record would most appreciate it. The FAA is not only screwed up, but they have been for 20 years in this business. I am appalled at what I heard this morning, and I will take on anyone who cares to debate the issue much further at any time.

The problem of seats breaking loose in takeoff and landing accidents is one that the scientific community has been trying to get the FAA to solve now for 30 years. I am sure you have heard today already that seats and tiedowns are much weaker than the human body and fail before the human body does. I am sure you have heard that there has been 30 years of research calling for stronger seats. But what you might not be aware of is that the FAA's own staff has been calling for over a decade for stronger energy-absorbent dynamically-tested seats.

If you will turn to page 6 of our testimony, you will see a chart showing the FAA's current seat strengths and seat tie-down strengths. You will see next to those a 1969 recommendation by the FAA's own staff calling for seats that are roughly twice as strong as they currently are now. Next to that, you will see a 1978 recommendation, again by the FAA's own staff, calling for seats twice as strong as they currently are now. Just as a way of comparison, I have put next to that the current Army standards for troop seats, which are in some cases 3 to 10 times as strong as current aircraft seats. Also, by way of comparison, I should note that car seats are from two to three times as strong as current aircraft seats.

Mr. Matthew Finucane, Director of the Aviation Consumer Action Project, expressed his concerns about seat strength standards:

We believe that the FAA is using research as an excuse to avoid requiring stronger energy-absorbent seats, because the airlines do not want to pay for developing, testing, and installing improved seats. While such costs concerns are objectionable in the first place, the irony is that improved seats would not really cost that much more.

[The referenced material follows:]

COMPARISON OF EXISTING STANDARDS WITH FAA STAFF RECOMMENDATIONS AND ARMY STANDARDS

[By gravity]

	Current FAA	1969 FAA aviation medicine recommendations	1978 FAA Mike Monroney Center recommendations	Current Army Standards for Troop seats
Forward	9.0	20	18.0	30
Downward	4.5	20	12.6	48
Sideward	1.5	10	3.0	20
Upward	2.0	20	5.0	8

(D) Runway Friction/Traction

Mr. James Burnett, Acting Chairman of the National Transportation Safety Board:

The Board has also been concerned about some aspects of airport operations during bad weather. Winter weather brings on problems caused by contamination

of runways by ice, snow, slush or standing water. These conditions, which can affect aircraft takeoff and landing performance as well as controllability, have long been of concern to the Board.

It has been long recognized that a reliable method to determine the friction coefficient of runways under dry, wet, icy or snowy conditions is essential. The use of a truck or an automobile with no special instrumentation to determine the slipperiness of a runway obviously does not bear much relationship to aircraft operations. Pilot braking reports are also unreliable and are merely a matter of opinion, with no basis for correlation to other aircraft. A more precise and repeatable method is needed.

Based on the events of the recent weeks, and on the long history of the inadequacy of runway slipperiness measurements, an all-out effort must be made to solve this problem that is with us both summer and winter and which can affect most seriously aircraft during both takeoff and landing.

Congressman Dunn questioned the NTSB on the issue of runway friction:

Mr. DUNN. I am going to follow up because I asked this question last week of Al Albrecht from the FAA. I have some reservations about the research dollars being spent on (runway friction) simply because of the fact that runway condition is not a measurable quality/quantitative thing that we can actually get a handle on.

In a condition of snow with two aircraft taking off ahead of me, if their wheels are throwing up some slush and my wheels are in a different portion of the runway. I am going to have a different friction basis than the two aircraft ahead of me. In a 9000-foot runway, if we have got a cloud over part of it and the temperature is 30 degrees you are going to have a different icing condition maybe 50 feet down that runway than you do 200 feet down the runway. So I have some real problems with research for any kind of equipment that can measure the total stopping or friction capabilities of a 9000- or 7000-foot runway.

What I am trying to say simply is that maybe we ought to take a look at how we not make those conditions on the runway rather than spending research dollars on how we determine what it is. And the idea I had last week for the FAA was something we use in the construction business called heat tapes. When you put heat tapes in a runway you simply don't have ice or slush, and I have asked the FAA to take a look at that as an alternative proposal.

My question to you is have you taken a look at that as a proposal? Do you understand what heat tapes are in the first place?

Mr. BURNETT. Yes, Congressman, and we will be considering that as part of our Boston World Airways investigation. This is probably an area that is going to need some research before we can determine the feasibility of it, but, again, what we are talking about here is research and development, and we feel there is a great need in the weather-related area or a great deal more progress needed.

Mr. DUNN. Well, what I am suggesting is rather than research and development on a vehicle that measures the conditions of runway how about research and development that gets rid of those conditions? It is a different type of research that I am suggesting.

Mr. BURNETT. I think that is a very positive suggestion.

Mr. DUNN. I thank you.

Mr. GLICKMAN. Going back to runway friction that Mr. Dunn raised, has the NTSB ever made recommendations to the FAA, specific recommendations, concerning runway friction?

Mr. BURNETT. Yes, we have.

Mr. Sweedler?

Mr. SWEEDLER. Yes, sir, we have made some recommendations that dealt with runway measurement, maintenance of runway surfaces to insure runway friction; we have made recommendations dealing with aircraft certification accelerate/stop criteria; and we have also made recommendations that dealt with flight simulated training on wet runways.

Mr. GLICKMAN. And have any or all of them been adopted by the FAA?

Mr. SWEEDLER. Most have, some have not. I think the one that has not dealt with the operational measuring on a day-to-day basis because of the difficulty in correlation between the testing vehicle and the aircraft stopping performance.

Mr. GLICKMAN. Did you recommend that there be a procedure by which runway icing, friction, wetness be measured on a continuous basis?

Mr. SWEEDLER. When there is water on the runway, yes.

Mr. GLICKMAN. And they have not implemented that recommendation?

Mr. SWEEDLER. My understanding is that there just isn't a vehicle that can really do that. Some progress is being made with a Saab friction vehicle and some testing is going on now with NASA and with some FAA-instrumented aircraft, but that has not really gotten to a point where it could be accepted.

Dr. Edmond Koenke, Director of the FAA's Technical Center summarized current research on runway traction:

Our runway surface traction program primarily addresses the potential reduction in runway friction levels on water covered runways. Our program involves research and development of friction measurement techniques and improvements of runway surface conditions to enhance aircraft braking and to reduce the chances of hydroplaning and loss of directional control under wet weather conditions.

Our program currently involves test and evaluation of various runway surface treatments, which include grooving techniques. This research is performed using the Naval Air Engineering Center's dynamic test track located at Lakehurst, N.J. The test process involves a jet test vehicle which accelerates, and brakes an air carrier aircraft tire wheel assembly in a track with controlled water depth conditions. You will note the wheel changing from normal braking to a hydroplaning condition as it leaves a grooved surface and enters upon a nongrooved surface.

I might note that we have recently installed a series of test configuration grooves in our primary runway at the FAA Technical Center. This will allow for a certain degree of in-surface evaluation of the effects of grooves, as a supplement to the dynamic test track procedures.

We have demonstrated the enhancements provided by runway grooving. We have also identified the cost/performance tradeoff associated with conventional grooving techniques. An experimental percussive grooving technique has been identified and has a cost savings potential in excess of 25 percent. This technique is currently being tested.

Future plans in this area consider design, durability, and maintenance of alternate surface treatments, tire/runway interface phenomena, and the design of a system for monitoring runway conditions.

With respect to snow and ice control we have developed airport maintenance and ground operations procedures to improve airport operating efficiency and safety. Airport advisory circulars have been issued which recommend snow and ice removal procedures based on the complexity and nature of runway operations.

Under a separate project, we have investigated the potential of a heated runway surface to preclude snow and ice buildup. Of the three systems investigated, electrical, steam and solar heat, the solar system appears to be the most cost/beneficial and is the most efficient in the utilization of the Nation's energy resources. However, while it is technically feasible to heat a runway surface, the capital and recurring costs for such an undertaking are a deterrent to implementation at this time. Installation costs on a single runway, for example, run in the area of $10 million, and that is 1975 dollars based on a 1975 study.

Congressman Dunn and Congressman Gore questioned Dr. Koenke on this issue:

Mr. DUNN. You came up with three different methods—heat tapes, steam air and solar—and your best guess was about $10 million per runway?

Dr. KOENKE. Correction. That wasn't the heat tape. I mean, it was an electrical way of heating the runway but not heat tape. The heat tape turns out to be much more expensive than either of those three alternatives.

Mr. DUNN. I guess my only reaction to that would be, as a general contractor in the construction industry who has installed heat tapes, your $10 million figure sounds like the old joke about what is an elephant, and that is a government mouse, a mouse designed to government specs. I put it in as a general contractor, and I find difficulty believing your $10 million figure. It can be done far cheaper than that, and I think it is an alternative to the kind of solutions that we have been proposing.

Mr. GORE. Let me ask you about runway friction. Isn't it true that there is equipment currently available that the operators of Logan Airport would have

used to determine the runway friction at the time of that incident, and that the FAA has just not required this even though it is currently available.

Dr. KOENKE. There are current ways of measuring friction.

Mr. GORE. We have got one parked out front, incidentally.

Dr. KOENKE. Sure, and there are many more than one way to do it. The problem is that they don't all correlate with each other for one thing. The other aspect of that question is bordering on regulatory issues and this is—you know, we are working in the R&D area and do not have control over the regulatory program.

Mr. GORE. Well, now, the Airline Pilots Association has already developed data that correlates the runway friction testers and the aircraft performance.

Dr. KOENKE. That's not the correlation I am talking about, excuse me. The correlation I am talking about is between the Mu meter, the SAAB, the various runway friction measuring devices. They do not all correlate with each other to give the same measurement.

What I am saying is that given the same conditions they don't measure the same number, and you have a problem correlating one system measurement to another system measurement.

Mr. GORE. The Mu meter and the SAAB vehicle. I'm informed, were correlated last September.

Dr. KOENKE. The Mu and the SAAB were, but the other devices are not.

Mr. GORE. Well, if we have one that is correlated and that works, and that is correlated with aircraft performance, why don't we use it?

Dr. KOENKE. That's a regulatory matter, sir. It is not a research matter.

Mr. GORE. Is there somebody on the panel that can speak to that? Why don't we use it if it is available? If Logan Airport had used that meter it could have provided data to the pilot of that aircraft telling him that he was going to slip off the end of the runway, but it is not required. Yet it is available. Why is that?

Mr. ALBRECHT. Mr. Gore, I really don't want to cop out on your question. It is a valid question. The point is, we are not the people who are competent to answer that question. That really is an aviation safety issue. I just really don't know. However, we can pass it on and supply it for the record if you would like.

Mr. GORE. Well, we will pursue it in whatever proper form with those who do have responsibility for it.

Congressman Gore asked Captain O'Donnell about runway friction measurement:

Mr. GORE. Captain O'Donnell, let me shift the subject and ask you about a specific safety improvement that could be made. In your prepared testimony, you say, "We have not attained the goal of being able to give the pilot accurate timely information about the condition of the runway." Do you think that the SAAB friction tester is an advance in that direction?

Captain O'DONNELL. We believe it is an advance in that direction, but we also believe there has been additional research done by NASA that really has not pushed out in the forefront along with SAAB. The gentlemen mentioned in our statement, with respect to a consultant at ALPA, is a gentleman who worked with NASA on this problem for over 25 years. We had the benefit of that background in our statement, that there is a tremendous amount of research completed. We think it is close enough where a little expedited additional research would produce the type of measurement equipment we are talking about.

Mr. GORE. Your consultant was the man who worked out of NASA; is that correct?

Captain O'DONNELL. That is correct—for 25 years.

Mr. GORE. And he developed the correlation between friction measurement and aircraft performance. You say that this method he used was well received at a technical conference last November in Seattle, and what is needed now is to have the FAA or NASA test his theoretical model, which you think works. Have you seen any indication that they are going to do that?

Captain O'DONNELL. No, Mr. Chairman. In fact, the opposite may be the case, because I think everybody is aware and the gentleman just mentioned it, that there is a substantial feeling in the industry that the FAA is cutting back on much of its R&D and this is one of the areas that could be very easily and quickly cut back.

Mr. GORE. I hope that will not be the case, but we will see.

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Captain O'DONNELL. I would like to say one other thing that I did not cover earlier. We did receive a very positive response from NASA on that runway friction testing comparative system. The only thing is, although they are ready to correlate it and go forward with it, it is sitting over at the FAA and we are getting no response. It is hidden in one of the closets over at the FAA, and somehow it has to be shaken out of there. I think that is something we could have had five or six years ago, with the amount of research done on it. I would hope that this committee would push the FAA to say, "Where is it? If NASA is ready to go ahead with it and put that program together, why not go ahead and do it?" It may have prevented the accident in Boston.

Mr. Bob Michael, Director of Aviation, Stapleton International Airport, Denver, Colo., responding to a question from Congressman Gore on runway friction measuring systems:

Mr. MICHAEL. I think, Mr. Gore, you put your finger right on the key word: correlation. The James brake decelerometer is a fine device that sits inside the vehicle. You step on the brakes and watch a needle based on how much friction you have, and you have some number that you can report. If you put that on the NOTAM, and the NOTAM comes up on air terminal information service, or maybe it goes out over local or ground control, and the pilot says to himself, "What's 32? I don't know what 32 is." Furthermore, "32" to a jet operator might be much more critical than 32 to a turbo prop operator, where you have those big reversible fans out front.

Mr. GORE. If you had correlation with each aircraft's performance—and we had testimony from the Air Line Pilots Association that their consultant has already done that, and they believe that if the FAA will check his methodology they will find it valid. That is a string of assumptions. But assuming that the correlation data are found, then it might be useful to a pilot; is that right?

Mr. MICHAEL. I agree, particularly during high-density operations on a specific runway where the conditions do not change much between one operation and the next. In fact, if you are looking for research suggestions, I think that is one where some attention could be given: a really solid look at the measurement of runway friction, not only during snow and ice but other kinds too.

(E) POST CRASH FIRE

Mr. James Burnett, Acting Chairman of the National Transportation Safety Board, summarized the concerns of the NTSB on aircraft cabin fire safety:

In 1979, and again in 1980, the Safety Board testified before the Committee on Public Works and Transportation of the House of Representatives regarding the frequent occurrence of post-crash fire in survivable air carrier accidents and on the effects such fires have on the materials surrounding the passengers in the aircraft cabin. Our concerns have not lessened in that regard. Statistics continue to show that about 20 percent of all air carrier accidents in passenger operations involve fire. About 25 to 30 percent of the occupants of these fire-involved aircraft die from all causes. About 15 to 20 percent of these fatalities die solely from the effects of fire or smoke. We were fortunate in 1980 and 1981 in that no fire deaths occurred in air carrier accidents during these years.

Thanks to the high level of interest of the Congress in this vital subject, the FAA, after nearly 20 years of dialogue, has embarked on an ambitious program to study the fire problem in a systematic manner. In the meantime, however, the National Aeronautics and Space Administration has made specific progress in the area of fire protection, specifically the threat from burning cabin interior materials such as polyurethene seat cushions, carpeting, decorative wall panelling and ceiling panels. In only two years of effort, the seat fire blocking concept, which consists of protecting the flammable seat cushions with thin layers of flame resistant materials, has resulted in the development and fabrication of seats in different combinations and configurations for testing. Ten seats already are flying in actual air carrier operations to test their operational characteristics such as comfort and durability. We are aware that full-scale fire tests have been performed on these seats and further tests are contemplated in the near future. Again, the Safety Board is very much encouraged by these developments and

hopes that these efforts will result in adequate interim standards for cabin interior materials.

Dr. Koenke, Director of the FAA Technical Center, outlined current research efforts:

I will begin with cabin fire safety, but to put this in context, this is only one element of a comprehensive post-crash safety program which encompasses structure crashworthiness, fuel fire prevention and cabin fire safety. Our objective of the cabin fire safety program is to increase the time available for safe passenger evacuation in the case of a cabin fire started and augmented by an external fuel fire, as well as to increase the time available to control a fire or safely land an aircraft in the event of an in-flight cabin fire.

The technical approach for improving cabin fire safety under this program are based on first understanding the problem, that is, "characterization of cabin fire hazards." This is accomplished by performing the most realistic large- and full-scale fire tests possible. The FAA Technical Center has extensive facilities for conducting this type of experimentation. Once the nature of the problem is adequately characterized and understood, three approaches to improved safety are available: management of fire, management of materials and management of people.

The FAA Cabin Fire Safety Program is a comprehensive program with major activities under each approach. A large number of activities are performed in-house at the FAA Technical Center while others are under contractual agreement with other Government agencies, including NASA and the National Bureau of Standards, and with private industry.

The cornerstone of the Cabin Fire Safety Program is the C–133 wide-body test article located in our large-scale fire test facility.

Shown schematically in this drawing, it is practically the size of a wide-body cabin. It enables us to evaluate improved cabin materials, safety concepts and systems under the most realistic conditions possible. For example, the effects of a large external fuel fire can be studied under controlled conditions usually not attainable outdoors. More recently, the C–133 test article was modified and used to study in-flight fires.

Now the question is how can we make the cabin safer? One way is to use a fire blocking layer to protect the relatively flammable flexible urethane foam cushions.

Seat cushion fire blocking layers are a concept that FAA believes can effectively improve safety. In this viewgraph of one of the 40 to 50 preliminary tests, the performance of the Vonar protected seat at the bottom versus the unprotected seat at the top at the identical test time, is striking. However Vonar carries with it a weight penalty of from three to four pounds per seat which, within this age of fuel conservation is prohibitively high. For example, over a 10-year period, a 3-pound weight penalty could result in a Boeing 747 aircraft using approximately an additional 200,000 gallons of fuel. Therefore, we entered into an interagency agreement with NASA to develop and evaluate low-weight fire blocking layer materials. In fact as a part of this agreement blocking layers and improved foams including polymere are being evaluated this week in the Douglas Aircraft Cabin Fire Simulator under a large-scale seat fire test conditions.

Other cabin safety projects include toxic gas analyses, burn-through resistant windows protective breathing devices, emergency lighting, in-flight smoke venting, and cargo compartment fire protection. Also, various activities deal with fire modeling, test method development and full-scale testing for the purpose of developing test methods for interior cabin materials. Cabin fire test methods and materials criteria data will be completed in 1983. We are confident that these efforts will yield further improvements in fire safety over the next several years.

Next, I will discuss external fuel fires. Some aircraft crashes result in damaged fuel systems, fuel spillage and large pool fires.

Based on past accident data, approximately 36 percent of the fatalities in otherwise impact-survivable crashes have been caused by fire. Although we have planned efforts to decrease this statistic through more crash resistant fuel systems, past efforts have indicated that prevention of the ignition of the spilled fuel, which is usually in the form of a fine mist, will prevent the formation of a fireball attaching to the aircraft. Prevention of such a fireball represents the highest probability of breaking the chain of events that leads to large pool fires and passenger fatalities. Hence in accordance with the SAFER Committee

recommendations major portions of our efforts are directed at the suppression of the tendency of turbine fuel to form fine mists when subjected to high velocity airstreams.

The current program, initiated in mid-1978 and fully defined in Engineering and Development Program Plan ED 18–4, Antimisting Fuel, consists of: 1) determination of the feasibility of the concept of antimisting, 2) identification of aircraft, engine and airport system-oriented problems, 3) research to provide solutions to these anticipated problems and, finally, a full-scale validation of the concept via flight test of a Boeing 727 aircraft and a crash testing of a Boeing 720 aircraft. The goal is to provide a technical data base to support a decision on implementation recommendations in mid 1984.

The work has resulted in the decision that use of the antimisting concept is technically feasible. This decision, reached in late 1980, was based on the results of evaluation of the most promising additive known as FM–9. This additive, originally formulated by The Imperial Chemical Industries, Ltd., of Great Britain, was the result of about 10 years work with the Government of the United Kingdom being the main sponsor of ICI Ltd.'s efforts. In 1978, the United States and the United Kingdom entered into a memorandum of understanding with the Royal Aeronautical Establishment and the FAA as signatories, and NASA as a third party, to conduct needed research. Since that time, the American counterpart of the ICI organization, known as ICI Americans, has taken over the development of this additive. Work conducted under this memorandum of understanding has identified various technical problems and our continuing program is designed to resolve these problems.

Dr. Jack Kerrebrock, Associate Administrator for Aeronautics and Space Administration, National Aeronautics and Space Administration, summarized current NASA research:

In direct support of the FAA's needs to improve occupant survivability in post-crash fires, Ames Research Center and the Johnson Space Center will complete development of fireworthy seat cushions and fabrics in Fiscal 1982. These will eliminate the most abundant sources of flammable materials in the aircraft. Thus, they are important for breaking the fire chain and improving aircraft safety. The thin, lightweight fire-blocking layer concept utilizes protective fire resitant wrappings over contemporary polyurethane foam cushions to minimize flame spread, heat build-up and release of toxic gases. The most promising configurations will be tested in the Douglas Aircraft Company's Cabin Fire Simulator starting tomorrow with industry witnessing these final tests. The Johnson Space Center/Solar Industries' development of fire resistant, lightweight and resiiient polyimide foam seat cushions has been completed. These cushions are about one-half the weight of contemporary polyurethane cushions, and in full-scale tests in the FAA's C–133 fire simulator have yielded dramatic improvements in fire resistance in a post-crash fire scenario. We saw that this morning.

The foam manufacturer has advised us that production capabilities are being developed. Three airlines are evaluating these cushions in scheduled flights.

Similar developments of lightweight, fireworthy interior ceiling, wall and flour panels are underway and will be continued. NASA will be providing these advance materials to the FAA over the next several months for full-scale testing in the C–133 facility.

The British-developed AMK, or Antimisting Kerosene Safety Fuel, FM–9, has shown in laboratory and in full-scale FAA tests the ability to prevent major fires caused by ignition of a jet fuel mist cloud. This cloud develops when jet fuel is suddenly released from wing tank structures during a crash, and in some accident scenarios it can be the dominant path for fire propagation from an ignition source to jet fuel spilled on the ground from ruptured tanks. The external fuel-fed fire then ignites the cabin materials. In Fiscal '82 the Lewis Research Center supported the FAA by completing evaluation of the compatibility of AMK fuel with the Pratt and Whitney JT–8D engine, the most common in-service engine. Engine components requiring modifications to accommodations requiring AMK were identified.

Mr. Matthew Finucane, Director of the Aviation Consumer Action Project, expressed his concern about the lack of action in cabin fire and post-crash fire safety:

Another area where FAA research is holding up the implementation of improved safety materials is in the area of post-crash fires. The FAA is working on antimisting kerosene, but it is not going to be available for over a decade. As for short-term efforts to stop the post-crash fire problem at its source, progress in this area has also been disappointing. In mid-1980, the SAFER Committee, on which we were represented, made short-term recommendations for rulemaking in the area of fuel tank vent protection, engine fuel supply shutoff, and modification of the flammability test now in use.

All of these actions should have been completed by now, but they have not been. There has been no notice of proposed rulemaking. They just have not done a thing. We think that a year-and-a-half after that SAFER Committee report, the FAA is a year-and-a-half behind in improving post-crash fire standards.

Another area I would like to touch upon briefly is the fact that cabin materials give off tremendous amounts of smoke and toxic fumes in post-crash fires. The FAA has no standards in this area. In 1977, they awarded a contract to McDonnell Douglas to develop standards. They gave them $400,000. McDonnell Douglas has given them the standard for smoke and toxic gases, and according to the FAA, in a quote from Science magazine, "It was a good effort, but it is not the final answer."

If we are going to have to wait for the final answer from the FAA before we get smoke and toxic gas standards, the question then becomes, Are there any materials that can be placed in the cabin today? We think there are. As the NTSB has testified, there are heat blocking layers for aircraft seats that can increase passenger evacuation time by 50 seconds. We think they should be installed now. Of course, rather than require these materials, the FAA is doing research into durability.

Concern for airline costs, not safety, is once again keeping a known solution on the shelf.

In conclusion, I again want to thank the committee for holding these hearings, and we think that this kind of oversight is absolutely essential if you are going to keep FAA research from just slipping and slipping for decades and decades, as it has done in seats and fires and collision avoidance systems in many areas.

(F) General Aviation Flight Data Recorders

Mr. James Burnett, Acting Chairman of the National Transportation Safety Board:

Before closing, Mr. Chairman, I want to raise another issue of special concern to the Safety Board. With respect to our study of the behavior of flight crews involved in accidents the Safety Board has a need for much more data on the flight crew's behavior in the cockpit and the effects of such behavior on the aircraft during an accident flight. To integrate the pilot's decision-making process into the overall accident picture not only requires accurate recall of what went on in the cockpit but also what effect these actions had on the aircraft. We need to be able to more accurately correlate the voice recorded data with the events recorded on the flight data recorder. State of the art equipment not only will tell us what actions the pilot took but it might be able to give us a better understanding about workload and mental overload, fatigue, and a host of other human factors, the knowledge of which are so urgently needed in the research performed by NASA today.

The Safety Board has advocated research and development of small, lightweight, inexpensive voice recorders and digital flight data recorders, so that their installation and use will be widely accepted by the general aviation community. The Safety Board issued several safety recommendations in 1978, which called for the development of recorders for complex general aviation aircraft. The Safety Board considered these recommendations so important that it has reiterated them eight times since their original issue. To date, no satisfactory requirement has been established.

Congressmen Glickman and Dunn raised this issue with the FAA:

Mr. Glickman. I would like to go for a moment to a question that Mr. Burnett raised about cockpit recorders in airplanes that are not required to have them now.

The NTSB said that despite eight reiterations of recommendations to the FAA no satisfactory requirement has been introduced with respect to cockpit recorders.

I wonder if that is because of the confusion in the state of research and development, or is it a regulatory decision?

Mr. ALBRECHT. Well, it is really not an R&D problem, Mr. Chairman. The companies are working on a small lightweight recorder. Westinghouse, for example, is doing this. It doesn't require an R&D expenditure, but the specification of a requirement is a regulatory action.

Mr. DUNN. You say it is not an R&D problem and, yet, Al, in the same breath you say that it is a weight problem. Doesn't that make it an R&D problem if it is too heavy for small aircraft?

Mr. ALBRECHT. Well, the recorders that Westinghouse and others are working on are very small and very lightweight. As you know, Mr. Dunn, current technology makes that a fairly easy thing to do. So work is being done in the commercial market, and normally when that happens, unless there is some outstanding reason, we don't feel it makes sense to spend the taxpayers' money do do the same thing.

Mr. DUNN. Is there an outstanding reason in the cost? Do you know what the cost involved for a small aircraft would be?

Mr. ALBRECHT. You won't like this answer. It is $7,000.

Mr. DUNN. You are right. I don't like it.

Congressman Glickman also asked DOD representatives about flight data recorders:

Mr. GLICKMAN. I would just ask one final question, Mr. Siewert. Has the Department of Defense developed a small, lightweight voice and flight data recorder applicable to general aviation?

Mr. SIEWERT. I do not know whether it is applicable to general aviation. We have just now started putting flight data recorders in the FA–18. This is the first aircraft the Department of Defense will have flight data recorders in. It is a digital system, all solid state, but I will have to get more of the details on that; I do not have them available.

Mr. GLICKMAN. Did you have an additional comment, Dr. Carper, on that?

Mr. SIEWERT. Dr. Carper has a different program in the Army that is broader-based than a flight data recorder.

Dr. CARPER. We recently developed and tested what we refer to as an Accident Information Retrieval System. It is a system that will give you both flight data and aircraft crash or accident data. It is an all-solid-state system. By itself, it has a microcomputer on board, and it compresses the data. For example, we have flown it on the Black Hawk aircraft in breadboard form, and at a 10:1 data compression, sampling only one-tenth of the time. We had exact plots with a fully-instrumented aircraft.

The crash data recorder portion of it is designed to give you initial impact conditions—that is, magnitude, direction, duration—of initial crash forces, plus it is designed to continue to work five seconds after crash to give you secondary crash forces. It is extremely difficult to get a flight data recorder on an Army aircraft, so we are in the process now of trying to combine that with other functions, such as condition monitoring and diagnostics on the aircraft, where we can go beyond scheduled maintenance and removal of parts and go with an on-condition removal of parts. So that is being referred to as a Flight and Maintenance Information System.

Mr. GLICKMAN. Do you have any cost estimates on these yet?

Dr. CARPER. On the accident information retrieval portion of it, the basic unit, in a weight sense, would be about seven-and-a-half pounds, with about another seven or eight pounds for installation. So we are talking about 15 pounds. The cost would be in the neighborhood of $10,000. I am sorry I do not have costs on the combined unit that would put the flight-data/crash-data in conjunction with maintenance data, but I can get that for you if you would like to have it.

Mr. GLICKMAN. Are you sharing this information with the FAA?

Dr. CARPER. Yes, sir. FAA and NTSB both are interested, and the Air Force and the Navy also.

(G) DISTANCE-TO-GO MARKERS

Congressman Dunn asked Colonel Try about their use of distance-to-go markers.

Mr. DUNN. A question for Colonel Try. Talking about the first few seconds of a takeoff an aircraft goes through V–1, which is virtually rotating speed, and V–2,

which is the point when a go/no-go decision must be made. Part of that function of V–2 is length of runway left available to that aircraft, and whether or not you tuck the gear and go throttle-back. To solve that problem, the Air Force has made the decision that runway-marker and distances-left-to-go is a practical means to help the pilot in that decision-making process, while the FAA has decided for commercial airports, I guess their rationale is that it is cost-prohibitive. Does the Air Force not find that it is cost-prohibitive to put runway-distance markers?

Colonel TRY. I would like to pass that comment to Mr. Siewert, in that we are not discussing the operational aspect of it, and I am not an expert in the operational aspects of flight safety.

Mr. DUNN. You would agree that the Air Force has made the decision to put runway markers in?

Mr. SIEWERT. Yes, sir.

Mr. DUNN. And you would agree that they are not at commercial airports?

Mr. SIEWERT. No, sir, they are not.

Mr. DUNN.. Is there any other reason than that the cost of signs might be expensive?

Mr. SIEWERT. I have no idea, sir.

If there are any questions along that line, we can certainly get the answer.

Mr. DUNN. I would appreciate knowing the rationale.

[The information follows:]

AVIATION SAFETY RESEARCH

Mr. DUNN. What is the rationale for the Air Force use of runway distance markers?

ANSWER. Distance markers were placed adjacent to Air Force runways during early 1950s to enhance pilot situational awareness during takeoff and landing phases of flight:

Markers were conceived as a logical and simple method to provide runway length information to pilots. Air Force recognized need to assist pilots in judging safe takeoff performance and landing deceleration characteristics based upon remaining runway length.

Addition of distance markers is historically linked to introduction of century series fighter aircraft (F–100) and heavy bomber aircraft (B–47).

Little, if any, empirical data provided impetus for initial installation. New aircraft prompted new pilot aids.

Runway distance markers provide a margin of safety unique to the operational/performance characteristics of each aircraft.

Markers provide visual cues during landing which allow pilots to determine required deceleration/braking techniques during instrument or night conditions.

Markers provide means for judging effectiveness of decleration/braking techniques and need for alternate braking or arrestment considerations.

Markers allow comparison of computed takeoff distance with actual travelled distance and rotation/liftoff capability.

Markers assist in takeoff about decisions by corrolating position on runway with stopping distances required under various meteorological conditions.

All Air Force runway distance markers conform with regulatory standards of size, illumination and runway proximity. This yields safety benefit when landing on unfamiliar runways.

In summary, runway distance markers are vital in both maintaining awareness of the aircraft/runway relationship and in fostering prompt decisions concerning safe actions when abnormal circumstance arise.

Congressman Gore asked the Airport Operators Panel about distance-to-go markers:

Mr. GORE. I am wondering about the distance-to-go markers. Do you think that is a good idea, and would that be too expensive to install at an airport your size, Mr. Wronkoski?

Mr. WRONKOSKI. No, I do not feel they are too expensive to install. We used them in the military, and I flew B–47's, which is a six-jet bomber, and I found them very useful.

Mr. GORE. So you think they would be a good idea?

Mr. WRONKOSKI. Yes, they give you a good idea of how much runway is left.

Mr. MICHAEL. I think it is a bit of a tinkering, and it might be what some of the people would call plussing.

Mr. GORE. Plussing?

Mr. MICHAEL. A slight additive to the system. I really do not think they are going to be of major significance in the overall scheme of things. If the weather is bad enough to begin with that you are having trouble seeing the runway markings, if the snow is coming down heavily, the chances are the pilot is trying to pay attention to keeping that airplane going right down center line, and he is not looking off right or left. One of the other guys is looking at the instruments as well. They are nice to have, particularly on deceleration as well, but I do not think they are necessary items in terms of overall safety.

Put it the other way around. If they had been, I am sure ALPA would have been on our backs a long time ago to have them in there. They are nice, and they are useful, but I wonder sometimes how the public sitting in the airplane reacts when they see it going "5", "4", "3", "2", "1" out the window. They are okay. I would not oppose them.

Mr. WRONKOSKI. I agree with Mr. Michaels. The main reason we used them was for extremely heavy takeoffs. That is when they were useful.

Mr. MICHAEL. But in really bad weather, snow, ice or heavy rain, they are not useful.

Mr. GORE. You cannot tell what the effect might have been with Air Florida. Of course, that is hypothetical.

Captain O'Donnell expressed his support for distance-to-go markers:

Another aspect of the runway that needs additional research is the markings. We believe more research is needed in runway lighting and marking to provide better guidance to the pilot during low-visibility approaches. Specifically, there is a need for better lighting to mark the runway threshold and for chevron markings and flashing lights to indicate more clearly to the pilot where the runway centerline is.

The major improvement in runway markings that we advocate is the installation of distance-to-go runway markers. These are boards set along the side of the runway at 1,000-feet intervals to show the pilot how much of the runway remains. They would be very useful in indicating actual aircraft performance on the runway during takeoff or landing and would also assist the pilot at those times when the runway surface markings were obscured.

The Air Force already has these markers installed on its runways. In 1975, we petitioned the FAA to require these markers on all air carrier runways. Two years later, the agency rejected our petition, saying that the cost of installation and maintenance of these markers outweighed the "limited benefits" expected. We think it is appropriate for the FAA to take another look at runway distance-to-go markers.

Mr. GLICKMAN. I would like to ask a question of Captain O'Donnell. I do not think Mr. Gore (asked you about) the question of distance-to-go markers, and I think in your testimony as well as in your remarks you indicate that this is something you have been pushing for a long time. For the life of me, I cannot understand why we do not do this. There is virtually no or little cost involved. I wonder if you could give me some idea why the FAA and/or airports have resisted distance-to-go markers?

Captain O'DONNELL. I think it is basically one thing: economics. Any place they can get out of spending money they will get out of it, and that includes the FAA and the airport operators themselves. I think it is a matter of priorities to the airport operators: they only have so much money, and they establish a priority. But I get concerned when they build expensive cocktail lounges and put big expensive monuments in the lobbies of the airports and do not give us basic safety items, such as the boards for runway-length remaining.

(H) NTSB FUNDING AND PERSONNEL

Congressman Glickman expressed his concern about the NTSB budget situation:

Mr. GLICKMAN. I am very concerned about your budget in this year and in the following year. Many of your recommendations have proved more dramatic

in enhancing air safety than anything done independently by any other agency, and yet I see that you are going to be left with a budget which will strain you rather dramatically.

I wonder, would an investigation on the scale of the Air Florida Flight 90 crash seriously deplete your budget for this year?

Mr. BURNETT. We are under a great deal of budgetary strain. We do not yet know how much the cost is going to be for the Air Florida investigation, because it is still continuing. What is now clear to us is that shortly after Air Florida we had the World Airways accident in Boston, and we were not able to give it the attention that we should have been able to because of lack of manpower and resources. And had we had another accident of that type in aviation at the same time we literally would not have been able to deal with it.

Mr. GLICKMAN. And if you would have had other kinds of transportation accidents too, it would have been almost impossible for you to have given it any proper investigative oversight.

Mr. BURNETT. We did have during that time. Aviation was not the only area in which there was a rash of transportation accidents during that period, and we were overextended. I really—there are none of our aviation experts able to be here at the table with me today simply because they are involved in Air Florida. We are stretched to the limits of our capability.

Congressman Glickman asked Mr. Burnett about recent criticism of NTSB appointments:

Mr. GLICKMAN. There has been some criticism that appointments to the NTSB, including yourself, do not represent the people experienced in transportation issues, whether they be aviation or whatever. I'm not sure of your background but I don't believe that you have an extensive background in aviation and that this agency has been alleged to be the receptacle of political appointments for people who may have helped in presidential campaigns, and it is not just this Administration but the past one as well.

I wonder if you would comment on that and comment on whether that causes you any problems in getting the FAA, who may have some people experienced in aviation, to listen to you? That is if they don't believe that you have a background in transportation but you are, so to speak, political hacks— and I say that for purposes of emphasis. Why should they listen to you at all?

Mr. BURNETT. In response to that I would say that there may be some value to having someone who is experienced in the political arena to maneuver the FAA into the position of having to do what they should do. I certainly hope that the political background that I have will serve me in good stead in that process. I recall the President's statement, when he was talking about the appointment of inspectors general, that he wanted people who are "meaner than a junk yard dog," and I think we have assumed the watchdog function, and I think it is helpful to have people who maybe not have abilities outside the technical field.

We have a very fine technical staff at the Safety Board. They are not public policy makers, and I think there is a need to have participation on the Safety Board of people who have that kind of perspective and that kind of background.

Mr. GLICKMAN. I guess my point is the concern that if you have people who are all there because of political reasons then you won't get that institutional acceptance by the regulators that you know what you are talking about.

Dr. C. O. Miller and Dr. Roland responded to questions on the qualifications of the NTSB members and investigators:

Mr. GLICKMAN. As you are aware, and both you gentlemen may wish to comment, there is no requirement that NTSB members have any experience in any transportation area whatsoever. There is legislation floating around here to mandate that, but I thought you might both want to comment on that.

Dr. MILLER. First of all, I think the investigation of Air Florida 90 demonstrates what the NTSB can do given proper leadership, motivation, and resources, and quite frankly I do not think they have had in recent years any one of the three. I think there have been some very severe investigation shortcomings of the NTSB and FAA work in recent years, particularly in general aviation. I think Flight 90 shows what can be done under the right circumstances.

I do believe, however, and perhaps more to the point of your question, that the recommendations that NTSB has given out are, in my judgment, consistently good. A lot of people take them as gospel. They are never put out to be gospel.

They are put out within the framework of the capabilities and background of the people there, but they do make people sit back and wonder, and to me that is the first step of research, and therefore it is helpful.

On your second point about qualifications, I have very recently sent a letter to the Senate Commerce Committee who, I guess along with Mr. Mineta in the House here, has introduced a bill requiring certain qualifications for all five board members. I never thought it would come to that. But quite frankly, in my experience in recent years, I have supported the bill, and I would limit my other comments to what is in that letter. I have made a copy of this available to one of the staff.

Mr. GLICKMAN. Thank you.

Dr. Roland, do you have any comments?

Dr. ROLAND. As far as I am concerned, in this area I did make a comment about the investigators in my testimony, the fact that they are not formally trained and I think they should be. Investigation today, as the aircraft become more sophisticated, with computer systems in them, some of the new natural phenomena that create things like ice where we did not anticipate ice, I think we need people with a little more formal investigation training than the investigators have.

As for the board, I think the board needs at least a core of technical competence in the field. Whether every member must conform to some standard, I do not think that is necessary, but I think they need a core of technical competence at that level.

Dr. Roland elaborated on his point:

At the present time, the National Transportation Safety Board does not have a school of formally-trained new aircraft accident investigators. Investigators receive their training in accident investigation on the job, working with experienced investigators. At this time, they are working with many formally-trained investigators; however, at some future time informally-trained investigators will be the instructors. There is a growing perception that the quality of the investigations has already degraded slightly. As time goes on, there is concern that this will continue with further quality decreases.

Accident prevention depends, in part, upon the quality of the investigation. There is a link between investigation and the resulting countermeasures and to the ultimate state of safety in the system. It is recommended that formal training for NTSB aircraft accident investigators be reestablished.

Mr. GORE. I am most impressed with the testimony of both of you. Was it you, Dr. Roland, who suggested that the NTSB investigators have scientific training, that you reestablish that requirement?

Dr. ROLAND. They do not have any formal training now.

Mr. GORE. But they used to?

Dr. ROLAND. They used to have a school, about a year-and-a-half to two years ago.

Mr. GORE. Why was that requirement removed?

Dr. ROLAND. I presume it was a funding problem.

Mr. GORE. A funding problem?

Dr. MILLER. I am certain it was a funding problem.

Mr. GORE. Now the investigators do not have to have any training?

Dr. MILLER. Just on the job, and I presume they hire people who——

Mr. GORE. Pick it up as they go along?

Dr. MILLER. I wish you were right. I do not believe that is true. They have people who have never investigated an accident, out on the scene for the first time in the company of another investigator.

Mr. GORE. That is ridiculous, it seems.

Dr. ROLAND. Yes, it seems that way to me also. Our contacts with investigators in aviation around the country have found that it has now reached a point where you can note that the investigation quality has degraded.

Mr. GORE. How long was that former requirement in effect?

Dr. ROLAND. How long did they have the school?

Mr. GORE. Yes.

Dr. ROLAND. A long time.

Dr. MILLER. A long time before I went to the board in 1968, I know that.

Mr. GORE. It was just done away with a year or a year-and-a-half ago?

Dr. ROLAND. Late '79 or early '80, I believe.

Mr. GORE. I think that the report that comes out of this hearing is going to have a large number of constructive suggestions. I think that these two subcommittees are going to remain very active in this area, following through on these recommendations. You two, in particular, have made a number of excellent suggestions, and I appreciate it.

Thank you, Mr. Chairman.

(I) FAA BUDGET

Congressman Glickman asked about the FAA budget situation:

Mr. GLICKMAN. I would like to ask Mr. Albrecht, General Ralph of the Air Transportation Association, who is going to testify later today, will testify that the FAA's R&D activities, many of which you showed there on your viewgraphs, will come to a virtual standstill as a result of budget cuts, and I would wonder if you care to comment on that.

Mr. ALBRECHT. I think that is a severe exaggeration, Mr. Chairman. We have perhaps no long-range plan for R&D activities which Mr. Helms has reviewed, and I believe he has indicated to the committee the kinds of expenditures necessary to support not only this program but the national airspace plan which has been submitted to Congress. And we expect that that plan will be supported and will be carried out.

Mr. GLICKMAN. Specifically on numbers, I realize we talked about a national airspace plan, and there is a lot of R&D that needs to be done, but specifically on dollar numbers of the program you were talking about here—icing, human factors, antimisting, crashworthiness and seats—are you going to be spending as much next year as you did this year?

Mr. ALBRECHT. We will be spending much more next year, Mr. Chairman. We expect to—but let me qualify that.

This year has been a bad budget year. This particular program did lose a substantial amount of support.

Mr. GLICKMAN. You are talking about the whole general——

Mr. ALBRECHT. No, the FE&D appropriation based on Congressional action.

We expect that will be restored next year and our program runs at the level of about $20 million per year. This year we are spending about $9 million. So this year has been a problem, but I think in the future that situation should not exist.

Mr. GLICKMAN. You say $9 million for Fiscal '82 on, again, the kinds of functions that were raised—basically in the operation of the tech center in Atlantic City and related functions?

Mr. ALBRECHT. Well, and also associated contract work. But I need to point out, Mr. Glickman, that we have reviewed our progress this year very carefully and in the documents we submitted to the committee you will see that we are on schedule with all of our Congressional commitments.

Mr. GLICKMAN. Okay, in terms of dollar amount, though, you say that you are going to try to spend about $20 million next year, Fiscal '83. You spend $9 million in Fiscal '82. What did you spend in Fiscal '81?

Mr. ALBRECHT. Around $21 million.

Mr. GLICKMAN. $21 million. So there was a dramatic reduction in this year's expenditures?

Mr. ALBRECHT. This year. Yes, sir, this year. That's not—we expect that's not a pattern.

Mr. GLICKMAN. I know the Administrator well. I'm sure that he has a serious intention to have the R&D activities, really air safety, as a high priority. And I don't think that the public will tolerate any dramatic reductions in those expenditures in the years to come.

Mr. ALBRECHT. There is no question of the Administrator's support, Mr. Glickman. We hope Congress supports it.

General Ralph was asked about his concerns regarding the FAA budget:

Mr. GLICKMAN. I would like to ask a question of General Ralph, because I could not help but be intrigued with your comments on the FAA's budget cuts, specifically the R&D budget. I would like you to comment on the difference between your testimony and Mr. Albrecht's testimony, because I think it is

significant. You basically state that the FAA's efforts are at a virtual standstill, and maybe I am reading something into what you said, but Mr. Albrecht clearly left the impression here that this was not true at all. That at least was my understanding. I think the implication from what I heard him say was that they had a reduction in fiscal 1982, but it was going to go up in fiscal 1983 to a level above what it was in fiscal 1981. I wonder if you could amplify on that.

General RALPH. I suppose your position depends upon where you are sitting at the time. The FAA technical center had a significant reduction in personnel in fiscal year 1981. They have a significant reduction in funding in fiscal year 1982. In building toward the capability to modernize the ATC system, the FAA is going to have to do additional significant research in systems and procedures for the new ATC system. The first of that money, hopefully, will appear in fiscal year 1983.

So my comments, I think, reflect circumstances that exist. We might argue whether or not I should use words like "dramatic" or "come to a virtual standstill," but there certainly has been a significant reduction in programs. There is a requirement for increased research programs to support the modernization of the ATC system, and I believe that it is a legitimate question to ask if the FAA is adequately funded to undertake these responsibilities.

Mr. GLICKMAN. Apparently then, what you are saying is that a big squeeze is going on: they are going to have to devote a lot of their dollars into the national airspace system, which then cannot be devoted into a multitude of other things.

General RALPH. Yes, aeronautical flight safety as opposed to ATC system safety.

(J) SEVERE WEATHER INFORMATION

Mr. James Burnett, Acting Chairman of the National Transportation Safety Board:

Weather is a significant factor in aviation accidents involving all types of operations—air carrier, commuter and general aviation. From 1975 to 1980 weather has been cited as a cause or factor in about 40 percent of the fatal U.S. general aviation and commuter accidents, and in 52 percent of the fatal U.S. air carrier accidents; 4,000 people lost their lives as a result of these accidents.

The Safety Board has been concerned with aviation weather problems for many years and has made numerous safety recommendations regarding weather facilities, services and procedures to the Federal Aviation Administration and the National Weather Service.

Over the years, the Safety Board has made a number of recommendations dealing with improving presently available weather equipment in order to insure expeditious dissemination of timely weather information to both air traffic controllers and pilots.

The need for this research was highlighted during the investigation of the crash of a Southern Airways DC-9 at New Hope, Ga., in 1977. The investigation revealed that water on the cover or dome over the radar antenna at the nose of the aircraft may have weakened the signal and presented the pilots with a false picture of the weather they were about to encounter. The board recommended that a study be made to determine the effects of water on the radar dome. As a result of this recommendation NASA is presently engaged in a program to evaluate the effects of precipitation on radomes. In addition, NASA is also studying the effects of rain on the lift and drag characteristics of the wings and horizontal stabilizers. We believe these programs should be given high priority.

Our concern in this area was highlighted again in June of 1980 with the crash of an Air Wisconsin turbo prop aircraft in eastern Nebraska. In strikingly similar conditions to the New Hope accident, the aircraft had encountered severe thunderstorms and experienced a loss of power due to massive water ingestion. As a result of this accident the Safety Board recommended that the FAA expedite the development of an integrated radar system having the capability of displaying accurate weather echo intensity information. We understand that the FAA is currently making progress in this area and that controllers have responded positively to the concept. The FAA will continue testing over the next several years and expects implementation of a system to begin in the 1984–1985 timeframe. We believe this is a very important program having sig-

nificant safety implications and that the program must be given high priority for completion.

Mr. Siewert, Director of Engineering and Technology for the Department of Defense:

Before concluding my discussion of our research programs, I would like to observe that integral to DOD flight safety efforts related to the environmental parameters of icing, wind shear, turbulence, lightning, and other severe weather phenomena are the research activities designed to improve observation and forecasting of these hazardous phenomena. The military services research, development, and operational weather service activities are involved in several interservice and interagency joint and cooperative efforts. The key coordinating arena for the environmental support activities is the Subcommittee on Aviation Services within the Office of the Federal Coordinator for Meteorological Services and Supporting Research. This committee is particularly active in weather service effects on aviation safety, as indicated by their February 1982 publication, "A Report on Improving Forecast of Icing Conditions for Aviation."

Finally, we must continue to improve our capability in weather observation and forecast. Here, the greatest potential lies not so much in increased research but in full implementation of the next generation weather observation Doppler radar program.

Dr. Edmond Koenke of the Federal Aviation Administration outlined their efforts on severe weather with emphasis on wind shear:

Finally, in the area of wind shear phenomenon, the FAA established six tasks: One, Wind shear characterization; two, hazard definition; three, wind shear data management; four, ground-based wind shear detection systems; five, integration of wind shear systems and data into the National Airspace System; and six, airborne wind shear development efforts.

The first three tasks: Win shear characterization, hazard definition and wind shear management have been completed.

One approach to ground-based wind sheet detection is a low-level wind shear alert system which is installed at 57 major airports in the United States. This system compares the wind difference between locations around the perimeter of an airport and a centerfield location and if a vector difference of 15 knots or more is measured, an alarm is triggered in the tower which, in turn, can notify the pilots of this event. Current planning for procurement of 60 additional systems for airports is underway.

Tests are also presently underway to detect and measure wind shear in the terminal area using an ASR–8 doppler radar technique to obtain wind shear and direction. Task 5, integration of wind shear systems and data into NAS, is currently an ongoing effort.

The sixth and last task deals with our work on airborne wind shear detection and measurement systems. Accomplishments to date include flight test evaluation of aircraft ground-speed measurement systems and flight demonstration of various cockpit displays using pilot aiding concepts. As a result of these efforts, wind shear profiles for flight simulation training have been developed and provided to the airlines.

Dr. Jack Kerrebrock, National Aeronautics and Space Administration outlined their severe weather research activities:

Low level wind shears have been the cause of several major airline accidents. Extensive research and development to forecast and detect shears from both the ground and the cockpit have been under way for several years.

Ames is continuing low altitude flight research on an airborne wind shear detector using an infrared radiometer with a range of 3 to 5 miles. The preliminary results of this research show that it appears feasible to remotely sense shears associated with gust fronts. We plan further evaluation of the radiometer in the NASA, FAA, NOAA, NCAR, NSF, and University of Chicago Joint Airport Weather Studies (JAWS) research at Denver's Stapleton Airport this summer. The JAWS program is vital to the accurate real-time characterization of severe wind shears associated with thunderstorm microbursts, simulation of aircraft performance and evaluation of wind shear detectors, warning and dissemination

systems. As part of the NASA structures research effort, the Langley B–57B research aircraft will participate in the JAWS research to measure the distribution of gusts across its wing span.

Clear Air Turbulence (CAT) research involves continued flight evaluations in the Ames C–141 aircraft of a NASA/JPL-developed microwave radiometer to detect CAT. CAT conditions cannot be forecast with the precision needed to guarantee avoidance. CAT encounters may result in passenger and crew injuries and, in extremely rare cases, aircraft damage and partial loss of control.

A major safety research program at Langley involves flight research in the unique F–106 storm penetrator aircraft. This specially protected and instrumented aircraft penetrates thunderstorms at high altitudes to collect detailed and precise measurements of direct lightning strikes to the aircraft. Data are also collected on turbulence, winds, x-rays and atmosphere chemistry. In order to conduct this research safely and to have confidence in getting direct strikes, Langley has developed advanced meteorology forecasting techniques which may evolve into routine operational tools in the future. During the last two years, twenty direct lightning strikes were recorded by the F–106 during the spring and summer sessions. NASA is planning to increase the sample size by several times this fiscal year. The direct strike data is needed for design of new lightning protection concepts for future aircraft employing composite materials, advanced electronic displays, microprocessors and digital flight and engine controls. By interagency agreement, this unique data is also being used by FAA and DOD to develop criteria for advanced technology aircraft. The wind and turbulence data collected by the F–106 is being used to further define a wind shear data base and is being correlated with similar data measured by the FAA/DOD/DOC advanced doppler weather radar. Ames is continuing research on the use of Head-Up Displays in low visibility and wind shear conditions.

Another meteorological hazard is heavy rainfall with and without wind shear. Tasks within this Langley program include the effects of water films caused by heavy rains on airborne weather radome and overall aircraft performance. The precipitation research is conducted in Langley wind tunnels and on the F–106 aircraft.

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